A Potential New Strategy for Stormwater Management in the Puget Sound Region

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Background

In the Pacific Northwest (PNW), as in many areas of North America, urban development is rapidly expanding into areas containing much of the remaining natural aquatic ecosystems. In the Puget Sound lowland ecoregion, the natural ecosystems most directly affected by urbanization are small streams and associated wetlands. These ecosystems are critical spawning and rearing habitat for several species of native salmonids. These fish, especially the salmon species, are of great ecological, cultural, and socio-economic value to the peoples of the PNW. Despite this value, wild salmonids are in considerable jeopardy of being lost to future generations. Over the past century, salmon have disappeared from about 40% of their historical range, and many of the remaining populations (especially in urbanizing areas) are severely depressed (Nehlsen and others 1991). There is no one reason for this decline. The cumulative effects of land-use practices, including timber harvesting, agriculture, and urbanization, have all contributed significantly to this widely publicized "salmon crisis."

Historically, the watersheds of the Puget Sound lowland ecoregion contained an abundance of complex, diverse, and productive salmonid habitat in the form of small stream ecosystems and their associated riparian areas. However, development of these lowland watersheds has significantly impacted the ecological integrity of these valuable aquatic ecosystems. The effects of watershed urbanization on freshwater resources throughout the United States are well documented (Leopold 1968; Hammer 1972; Hollis 1975; Klein 1979; Arnold and others 1982; Booth 1991; Schueler 1995). They include extensive changes in basin hydrologic regime, channel morphology, and physiochemical water quality. The cumulative effect of these alterations has produced an instream habitat that is significantly different from that in which salmonids and associated fauna have evolved. In addition, development pressure has a negative impact on riparian forests and wetlands, which are essential to natural stream functioning. Considerable evidence of these effects exists from many studies of urban streams in the PNW (Perkins 1982; Richey 1982; Steward 1983; Scott and others 1986; Booth 1990; Booth and Reinelt 1993; Taylor 1993; May and others 1997). The cumulative effects of watershed urbanization in the Puget Sound lowland region have resulted in a loss of natural forest and wetland cover, as well as a significant increase in impervious surface area. Riparian forests, floodplains, and off-channel wetlands have also been severely degraded by the incremental encroachment of residential and commercial development. The decline in ecological integrity of the stream-riparian ecosystem appears to begin at very low levels of watershed development and continues with increasing watershed urbanization (Figure 1).

Research Findings

Beginning in the early 1990s, researchers in the Puget Sound region began to study the linkages between watershed development and the ecological integrity of our freshwater ecosystems (Horner and Reinelt 1995; May and others 1997; Horner and May 1999). The initial studies focused on establishing the causes and effects of water quality degradation in Puget Sound lowland streams and wetlands. These early studies identified several key findings, including:

1. There is no single cause for the decline of water resource conditions in urbanizing watersheds. Instead, it is the cumulative effects of multiple stressors that are responsible for reduced stream "health." Imperviousness, while not a perfect "yardstick," appears to be a useful predictor of watershed condition. Only streams with very low levels of watershed imperviousness retain their natural ecological integrity.
2. There are multiple "scales" of impact that are operating within each watershed. These include landscape impacts including the loss of natural forest cover and the increase in imperviousness throughout the watershed. There are also "local" effects such as water diversions, stream

channelization, streambank hardening, and culvert installation. All these stressors contribute to the overall cumulative impact.

3. There is no clear "threshold" of urbanization below which there exists a "no-effect" condition (see Figure 1). Instead, there appears to be a relatively continuous decline in almost all measures of water quality or ecological integrity.
4. While the decline in ecological integrity is relatively continuous and is consistent for all parameters, the impact on physical conditions appears to be more pronounced earlier in the urbanization process than chemical degradation. It is generally accepted that it is the shift in hydrologic conditions that is the driving force behind physical changes in urban stream/wetland ecosystems.
5. Measures of biological integrity are the most responsive and integrative indicators of overall aquatic ecosystem "health".

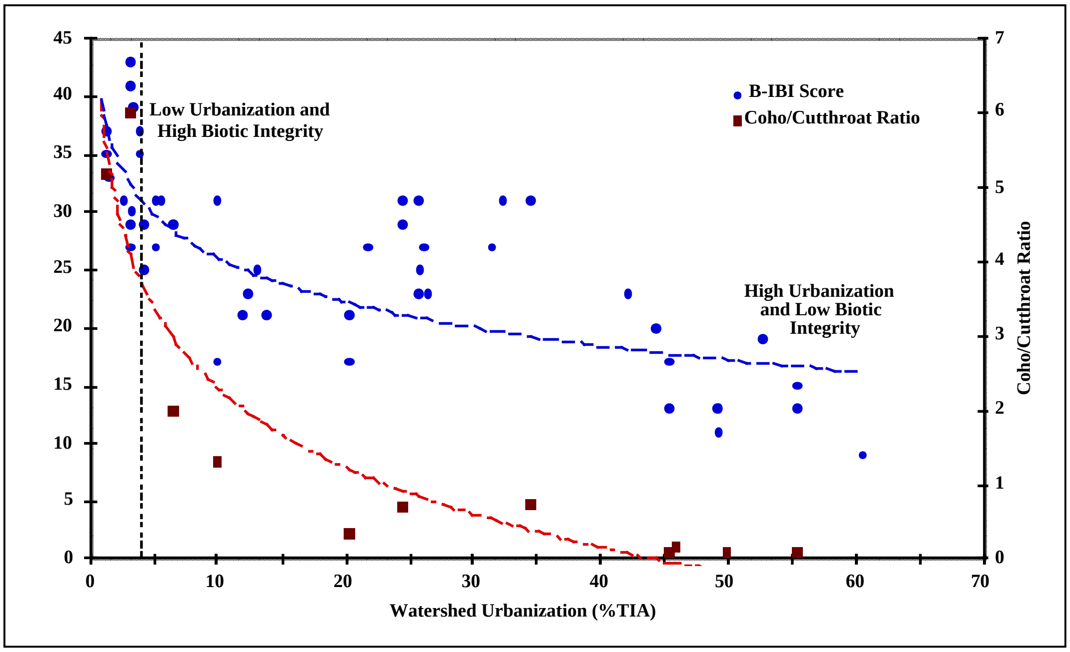

Figure 1 Relationship between watershed imperviousness and biological integrity in the Puget Sound lowland ecoregion (May and others 1997).

During these regional studies of urbanizing watersheds, it also became apparent that so-called riparian "buffers," if designed and maintained so as to emulate natural riparian conditions, could have a significant mitigating influence on the ecological degradation of streams and wetlands in urbanizing watersheds of the Puget Sound lowland region (May and others 1997). This was reflected in higher than expected levels of biotic integrity in those stream reaches with wide, continuous, and naturally vegetated riparian corridors. Research findings indicate that streams with a high level of riparian integrity have a greater potential for maintaining natural ecological conditions than do streams without a natural riparian management zone (RMZ) (Horner and May 1999). In addition, streams with a RMZ that retains a high level of riparian integrity, in general, also have a higher level of ecological integrity than streams in watersheds where a structural BMP strategy is the primary mitigation strategy (Horner and May 1999). Figures 2, 3, 4, and 5 show these results. For this analysis, "riparian integrity" was defined based on the results of Puget Sound lowland studies and rated as either present ("w/riparian" in Figures) or absent ("w/o riparian" in Figures). Riparian integrity was defined by buffer width (> 70% of corridor wider than 30 m and < 10% of the corridor under 10 m in width), riparian continuity (< 2 breaks in the corridor per km of stream), and riparian quality (> 80% of the corridor as forest or wetland cover). Based on the results of Puget Sound lowland studies, the use of a variable width riparian RMZ that will include the structural and functional components of the natural stream-riparian ecosystem, as well as floodplain or CMZ considerations is strongly recommended. Retention of a wide, continuous riparian zone in forest cover or wetlands has shown to be the BMP of greatest potential and versatility among those in current use (Horner and May 1999). This practice may also be the simplest to accomplish logistically the least costly and, accordingly, the most cost-effective. In newly developing areas, riparian zones can be isolated from development, along with their associated streams, which are not going to be built over in any event. In already developed landscapes, riparian zones are often the least developed and could more easily be bought and put into protective status than upland areas. Riparian retention also fits nicely with other objectives, like flood protection and provision of wildlife corridors and open space.

The scientific principles that form the foundation for delineation of riparian management zones and buffers include the following:

- Maintain or restore the freedom of movement of stream channels to move and change within their natural CMZ based on environmental conditions.
- Maintain or restore the connection of the stream to its floodplain, including off-channel habitat, riparian wetlands, and side-channels.
- Allow natural regenerative processes to occur without undo human intervention. Restoration efforts should not conflict with natural processes.
- Protect or enhance biodiversity and habitat complexity within the stream-riparian ecosystem. Recognize and nurture the complexity and diversity of nature. Do not try to mold streams to suit human-based constraints.
- Support or reestablish the longitudinal connections within the stream-riparian corridor. The interactions of headwater areas, mainstem channels, tributaries, and estuaries are critical to the proper functioning of the watershed.
- Site-specific modifications must always consider the cumulative impact of that action and how the site plan fits into the watershed as a whole.

As the above discussion indicates, a one-size-fits-all buffer likely will not work. This would argue for a watershed-by-watershed, stream-by-stream, and site-by-site approach. This integrated, hierarchical approach may look to be a daunting and costly task, but it is necessary if we are to conserve our aquatic resources, protect of water quality, and improve our quality of life. The use of riparian buffers is only one component in an effective watershed management approach. Because of the diverse and pervasive nature of development impacts, buffers alone are likely not adequate. A combination of riparian buffers, land-use limits, and an aggressive stormwater treatment program may be the best strategy (Horner and May 1999).

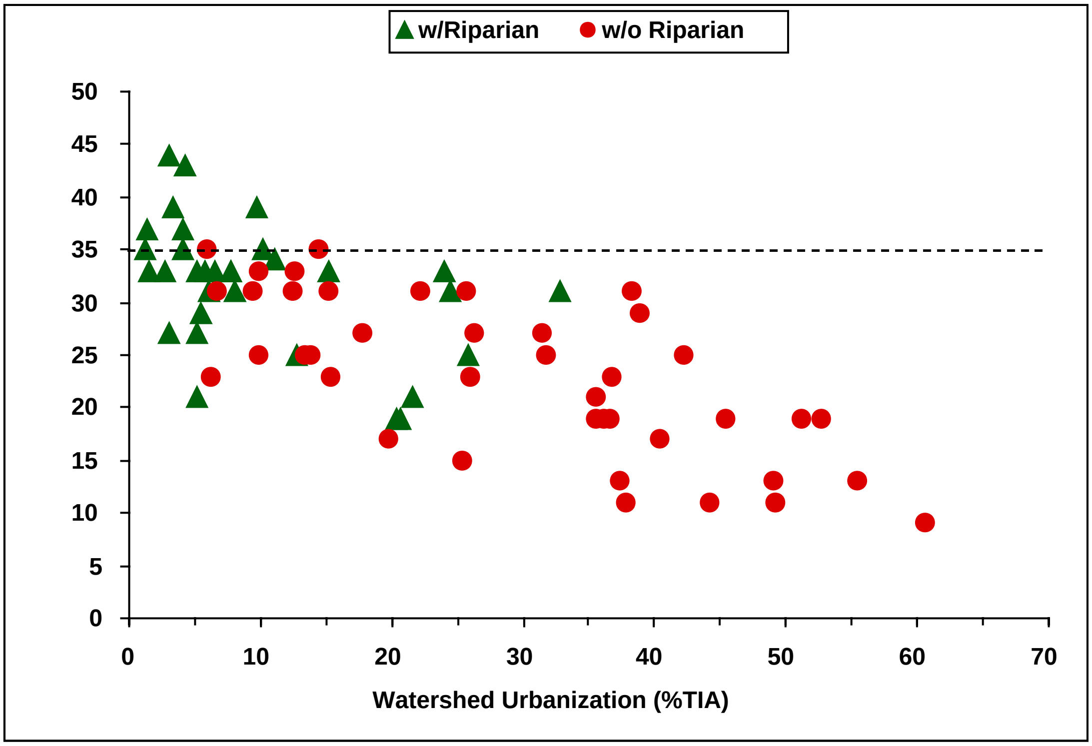

Figure 2 Relationship between watershed imperviousness and biological integrity, as measured by the multi-metric benthic index of biotic integrity (B-IBI), showing the apparent mitigating effect of riparian integrity on biologic conditions in Puget Sound lowland streams (May and Horner 2000).

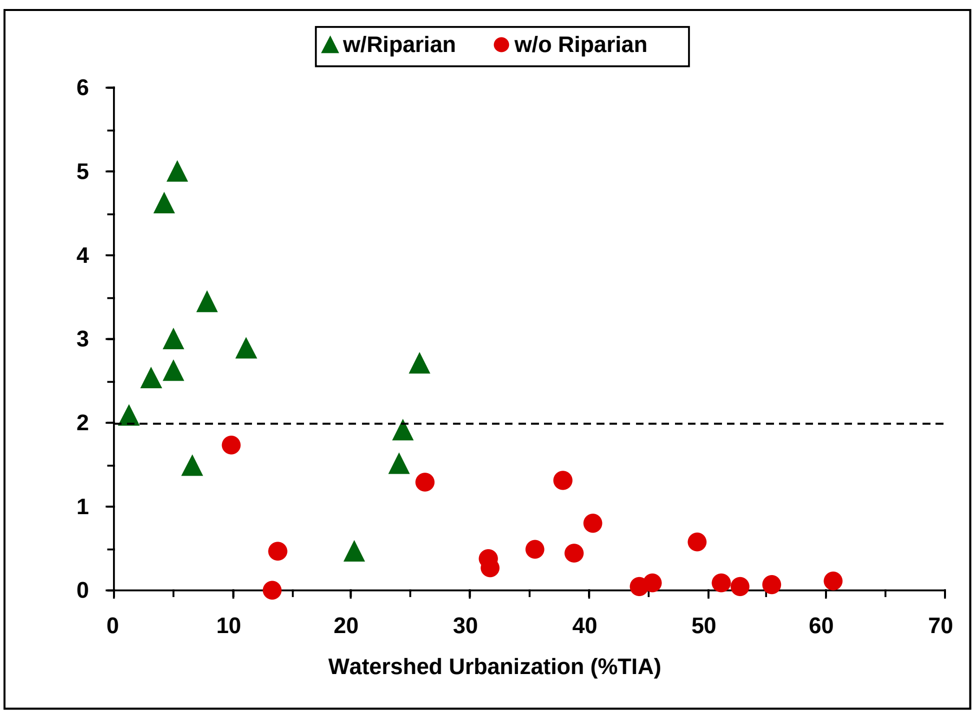

Figure 3 Relationship between watershed imperviousness and biological integrity, as measured by a juvenile salmonid index, showing the apparent mitigating effect of riparian integrity on biologic conditions in Puget Sound lowland streams (May and Horner 2000).

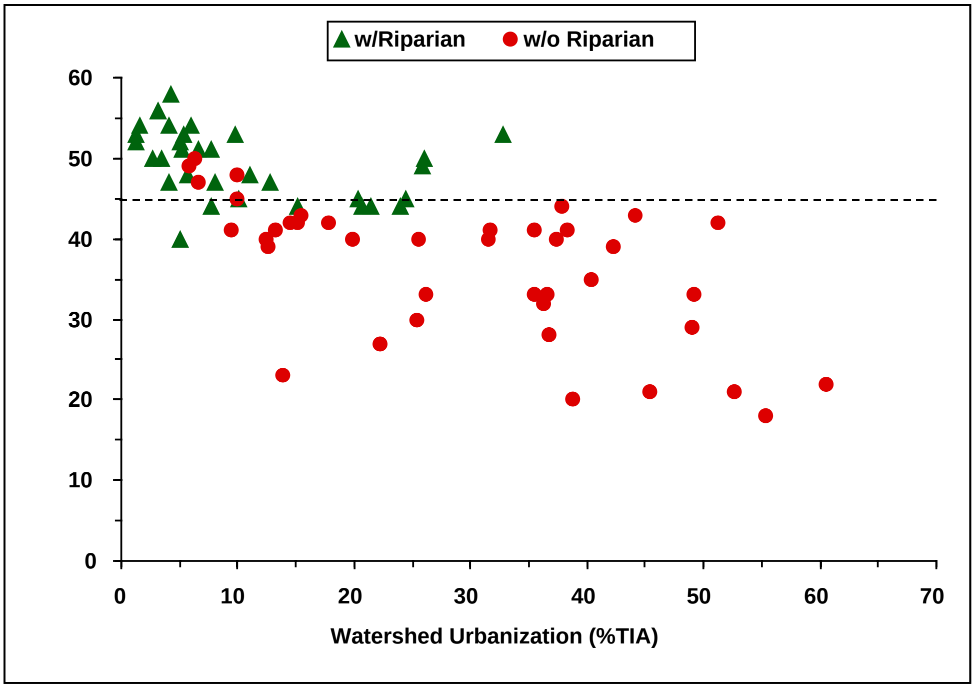

Figure 4 Relationship between watershed imperviousness and instream habitat quality, as measured by the multi-metric qualitative habitat index (QHI), showing the apparent mitigating effect of riparian integrity on ecological conditions in Puget Sound lowland streams (May and Horner 2000).

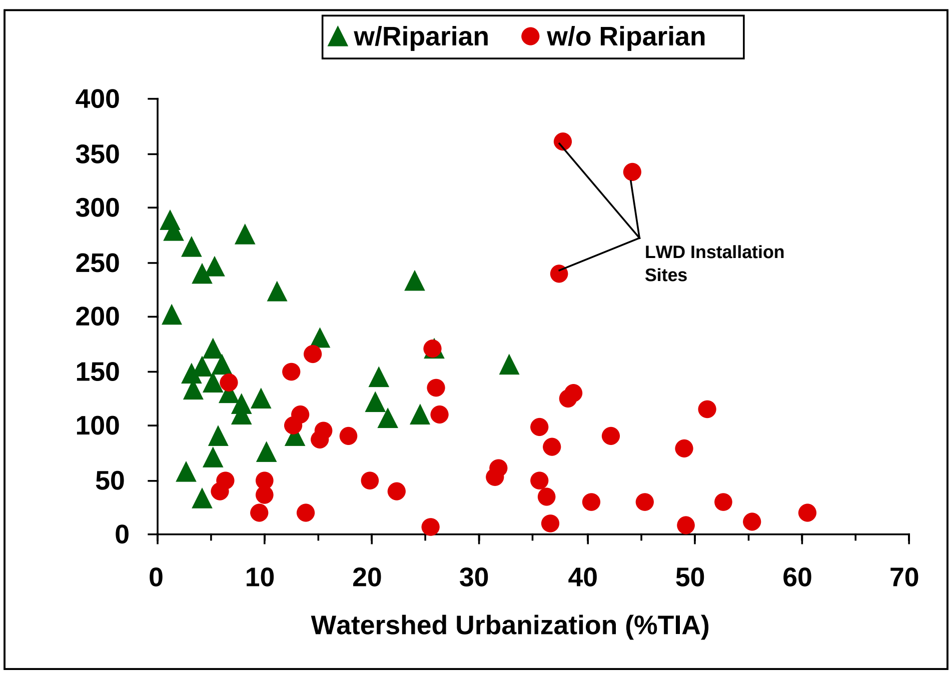

Figure 5 Relationship between watershed imperviousness and instream habitat quality, as measured by large woody debris (LWD) frequency, showing the apparent mitigating effect of riparian integrity on ecological conditions in Puget Sound lowland streams (May and Horner 2000).

In follow-on studies (Horner and May 1999), structural stormwater BMPs were demonstrated to have an appropriate place in urban water resources management but to fall far short of supplying all needs, in contrast to thinking prevalent in most stormwater management programs. It appears that these BMPs have their most potential for benefit at the medium and higher urbanization levels, where they seem to have some positive effect on fish as well as invertebrates. While studies have shown the benefits of structural BMPs in chemical water quality treatment, the evidence is that they offer little flexibility to increase urbanization and still have the best overall ecological integrity in relatively pristine cases, unless exceptionally large numbers of, presumably, high quality BMPs were to be installed. With additional investigation of BMP quality pending, little on a specific level can be said about the role of BMP quality standards in this picture. However, it can be concluded that a mitigation strategy that relies solely on structural BMPs will not maintain natural levels of ecological integrity (see Figures 6, 7, 8, and 9). More certain of success, though, would be to limit severely the installation of impervious surface and rely to the degree possible on non-structural BMPs that retain natural soil and vegetation cover. In addition to riparian forest conservation, general forest retention throughout watersheds was also shown to offer important potential mitigation benefits, just not as extensively as riparian retention. Forest retention should be a high priority especially in managing the growth of undeveloped and lightly developed watersheds, in connection with impervious surface limitation and riparian protection efforts. Most likely, the potential benefits shown for riparian and forest retention could be compounded by pursuing both in concert. Full coverage of otherwise unmitigated development with structural BMPs should be specified after all possible use of non-structural techniques.

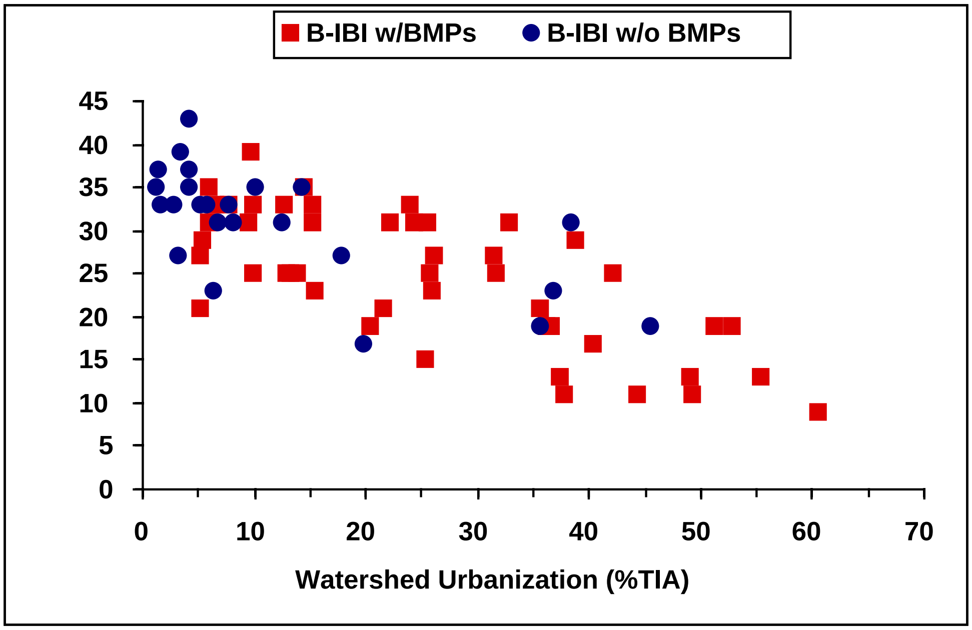

Figure 6 Relationship between watershed imperviousness and biological integrity, as measured by the multi-metric benthic index of biotic integrity (B-IBI), showing the lack of mitigating influence of structural BMPs on biologic conditions in Puget Sound lowland streams (Horner and May 2000).

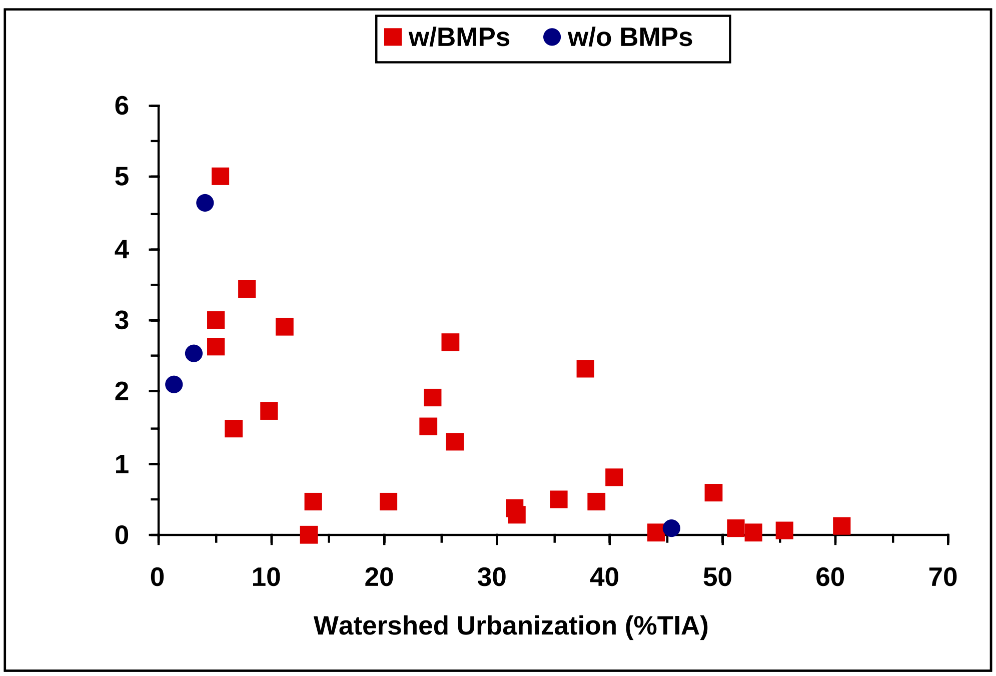

Figure 7 Relationship between watershed imperviousness and biological integrity, as measured by a juvenile salmonid index, showing the lack of mitigating influence of structural BMPs on biologic conditions in Puget Sound lowland streams (Horner and May 2000).

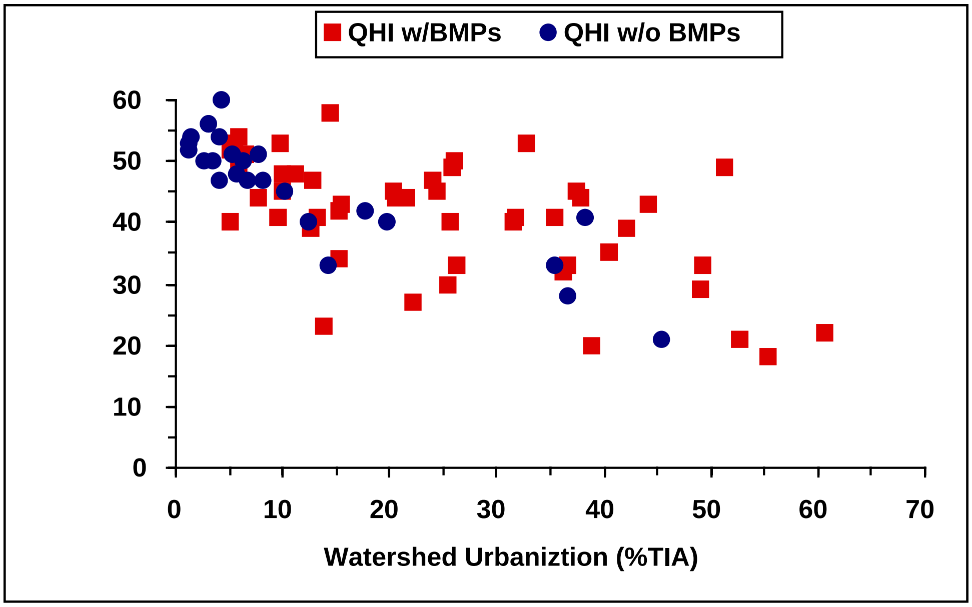

Figure 8 Relationship between watershed imperviousness and instream habitat quality, as measured by the multi-metric qualitative habitat index (QHI), showing the lack of mitigating influence of structural BMPs on ecological conditions in Puget Sound lowland streams (Horner and May 2000).

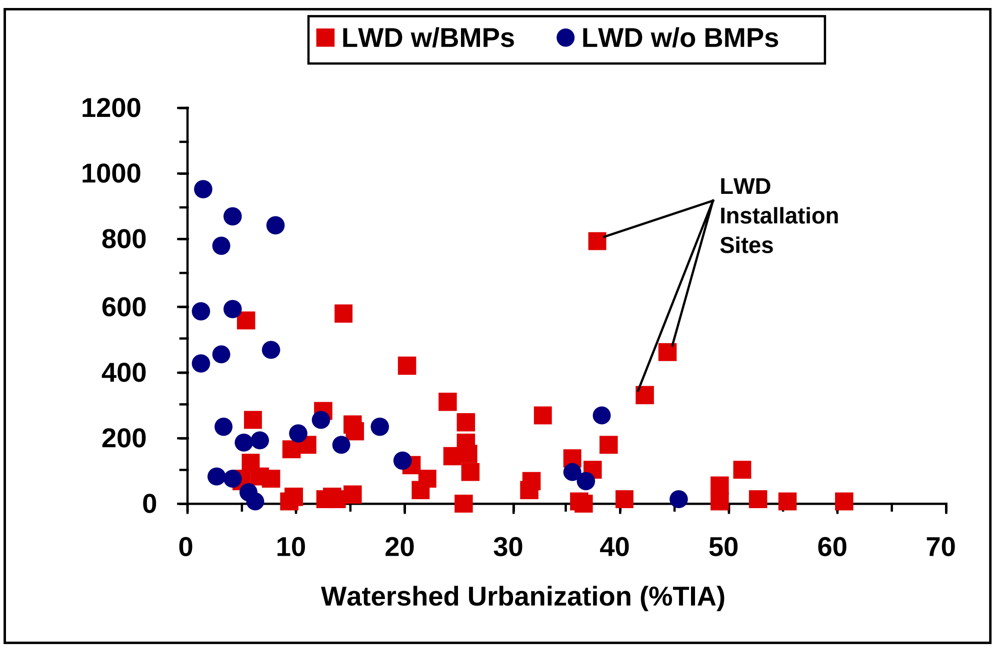

Figure 9 Relationship between watershed imperviousness and instream habitat quality, as measured by large woody debris (LWD) frequency, showing the lack of mitigating influence of structural BMPs on ecological conditions in Puget Sound lowland streams (Horner and May 2000).

The results presented here show that the relatively recently introduced initiatives such as conservation design and low-impact development, that preserve natural forest cover and minimize imperviousness, have considerable promise. On the other hand, the findings point out as well that these methods are not applicable to pursuing all goals and have limitations. Further, the results suggest that the capabilities of non-structural set asides can become overwhelmed at some level of development. With neither structural nor non-structural mitigation offering us unlimited ability to maintain natural ecological conditions while continuing to develop land as we have been, we should be prepared to prohibit or very severely limit development around the streams still offering the greatest ecological goods. For these last best places, the watersheds and the streams they drain should be preserved as public resource lands and private land trusts. Extensive measures of this magnitude will be required if the Pacific Northwest is to observe the Endangered Species Act and save its salmon.

In closing we want to reiterate that the foundation of any effective environmental management effort, such as this discussion implies, must be ecological goals developed with firm knowledge of what the system is capable of in different circumstances and what it needs to flourish at certain levels. Goals should be stated in concrete and measurable terms. Management actions must be prescribed with reference to the ecosystem's needs and tolerances and the capabilities of the alternative actions to meet those requirements. Drawing these linkages requires extensive research on system functioning such as we are now conducting. We urge water resource agencies and others to vigorously and generously support such research focusing on the systems in their trust.

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